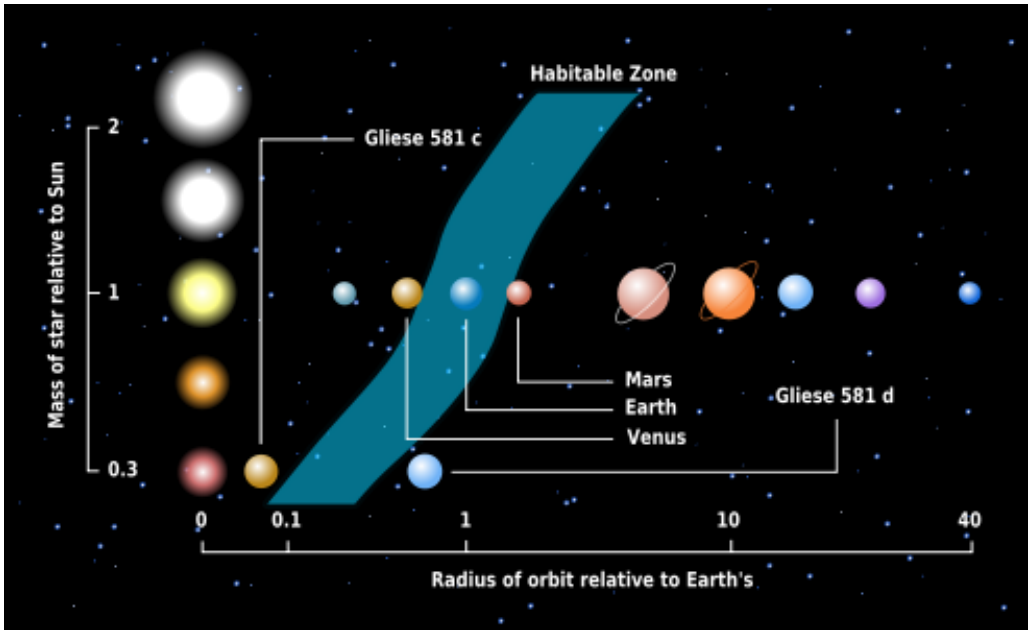
Life In The Universe

What is extraterrestrial life?

- We can only scientifically approach the question of existence of extraterrestrial life which is sufficiently similar to ours.
- We may not recognize as life some space – dwelling creatures feeding on gravitational waves.
- However, we can study whether life can exist with a different molecule from DNA as a genetic carrier.

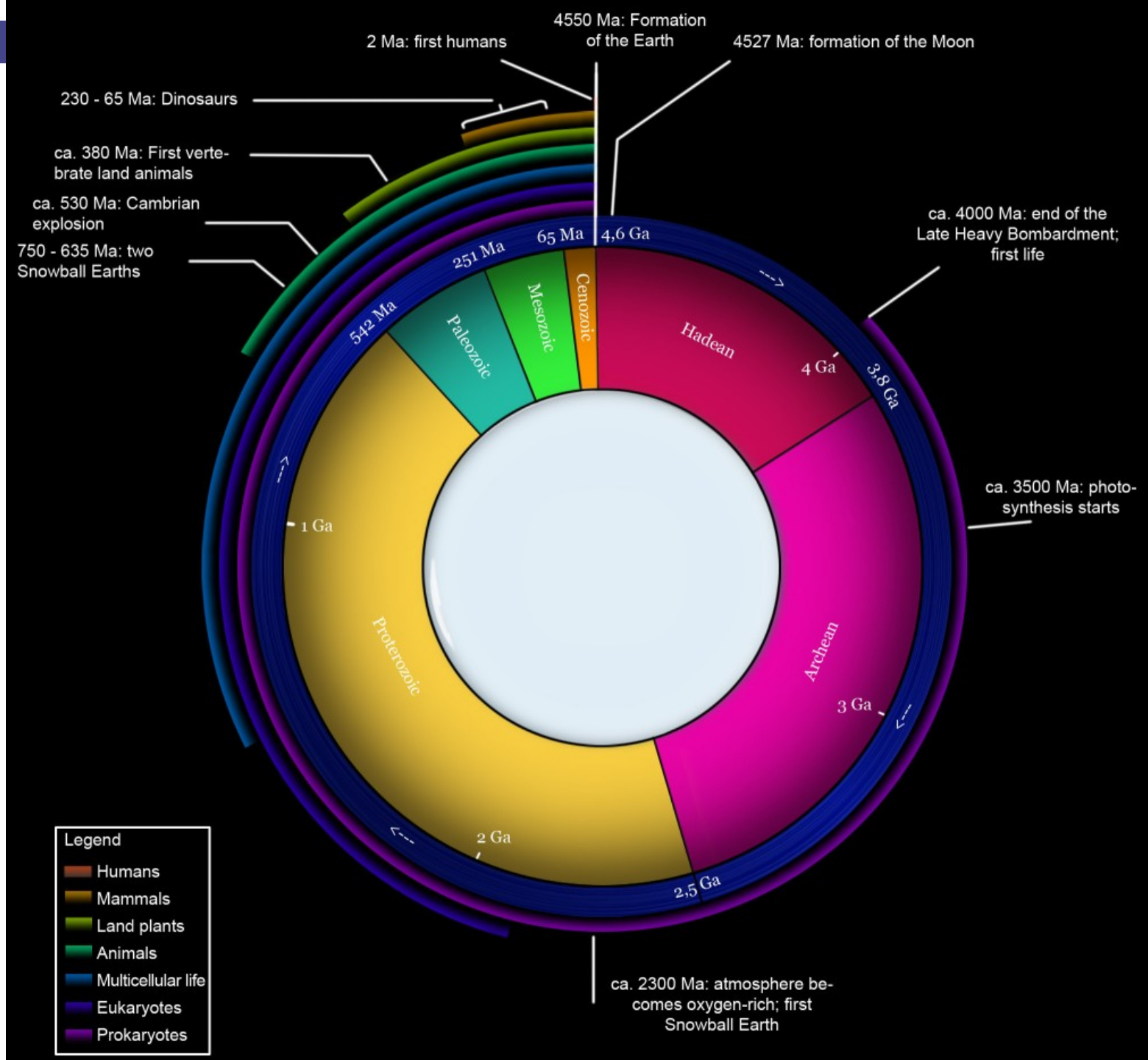
Habitable Zone

- Zone around a star where liquid water can exist.
- The fainter the star, the closer to it is its habitable zone.
- Liquid water is presumed to be a necessary condition for life.



Life on Earth

- Starting point: interstellar molecules.
- Conditions: oceans within 150 Myr after the Earth formation.
- Likely frequent bombardment by meteorites, comets, and even asteroids.
- Ocean temperatures up to 200^{o}C (very high atmospheric pressure).
- Never-the-less, first life formed about 4Gyr ago, only 600 Myr after the formation of the Earth.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4 Ga
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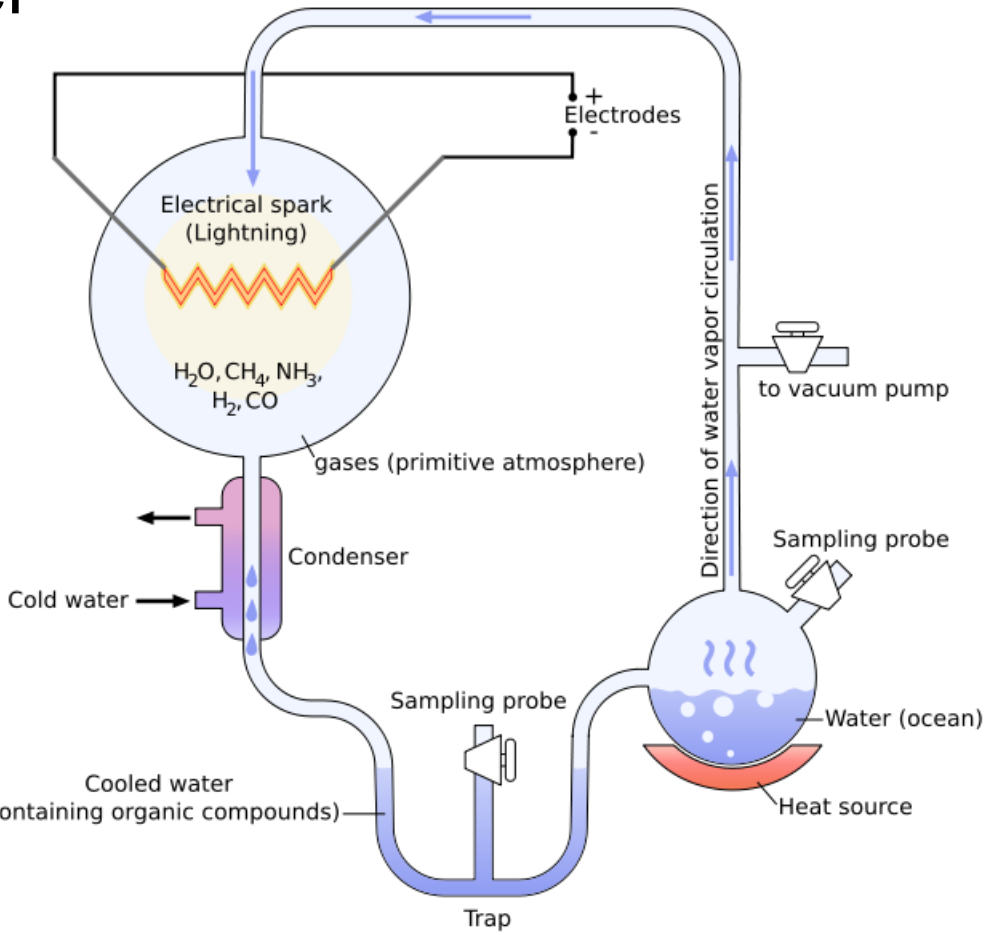
3 Ga
2,5 Ga
2 Ga
1 Ga
Legend
Humans
Mammals
Land plants
Animals
Multicellular life
Eukaryotes
Prokaryotes

Miller – Urey Experiment

- 1953 by Stanley Miller and Harold Urey at the UofC.
- Run for 1 week.
- 2-3% of all carbon formed ***amino acids***.
- Also formed sugars and lipids.
- No nucleic acids.

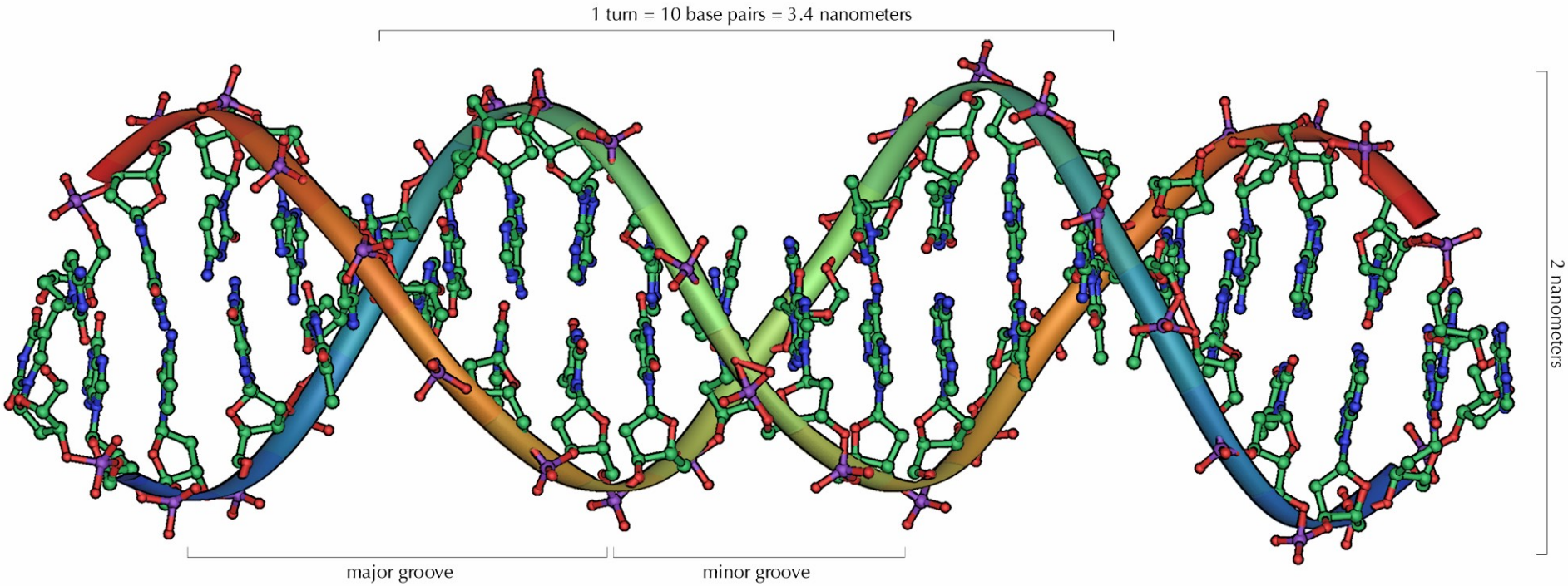


Mystery of Homochirality

- Like human hands, amino acids have two different orientations, or ***chiralities***.
- Only left-handed ones are present in living organisms.
- Right-handed ones are either biologically inactive or plain toxic.
- In Miller – Urey experiment both chiralities formed in equal proportions.
- Where did right-handed amino acids go?

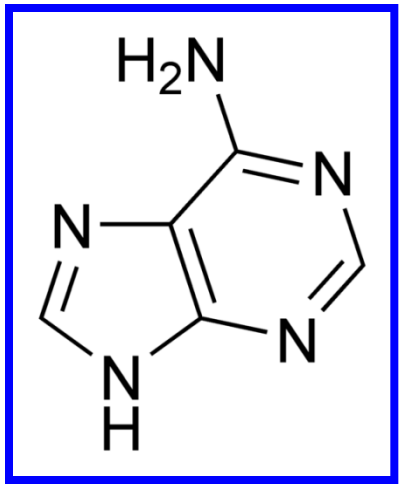
DNA

- Deoxyribonucleic acid is a basis of all life on Earth. It is a carrier of all genetic information.
- It is a double spiral made of 4 main bases.

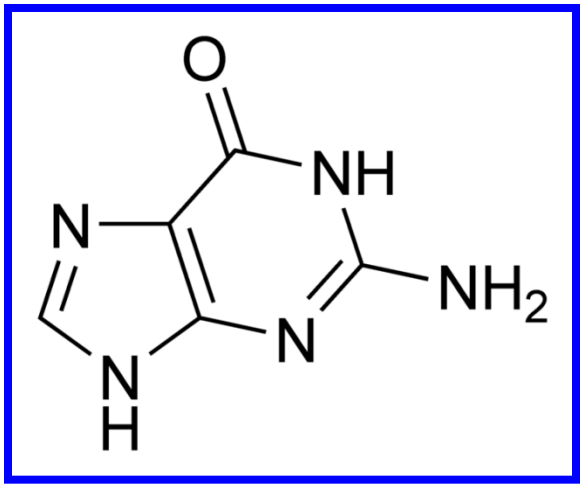


Another Fantastic Four

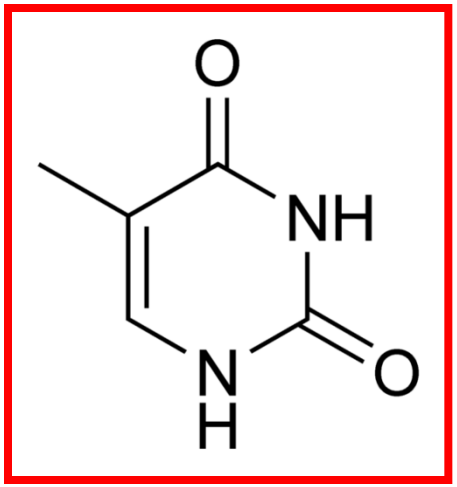
- DNA is made of 4 main bases: A (adenine), G (guanine), C (cytosine), and T (thymine).
- A and G form in freezing conditions, C and T at boiling temperatures.



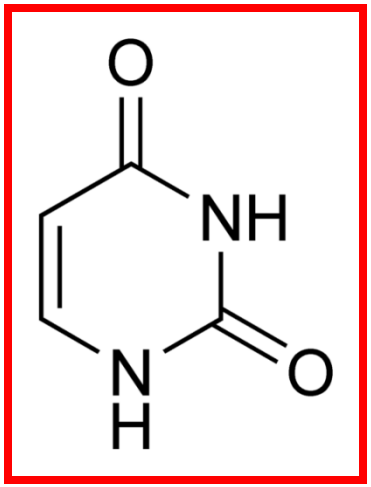
Adenine



Guanine



Cytosine



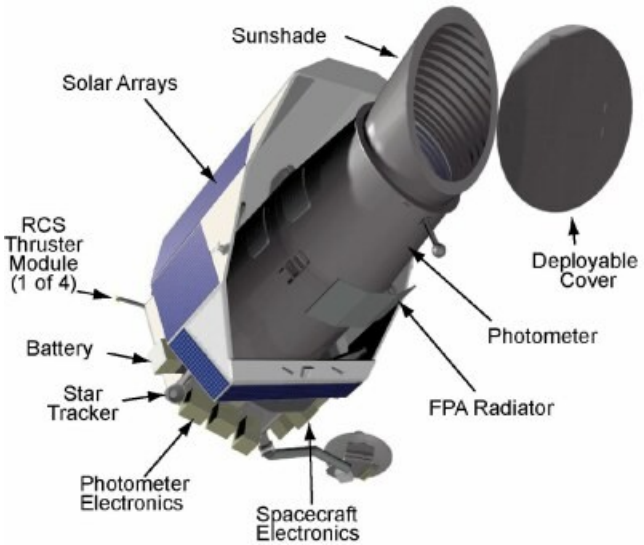
Thymine

Question:

- How can a DNA molecule form?
  - **A**: one end of the molecule should be in ice, another end in boiling water.
  - **B**: half of the molecule forms in a chunk of ice, which gets vaporized in a geothermal vent later.
  - **C**: aliens' help is required to form it.
  - **D**: how am I supposed to know?

Astrobiology

- Study of life in the universe: an interface between astronomy, biology, and geology.
- Two-prong approach:
  - Search for life in the solar system (Mars and Europa, perhaps Titan).
  - Search for terrestrial planets around other stars (NASA Kepler mission, Mar 2009, monitor 100,000 stars for transits).



Intelligent Life

- Life on Earth formed rather fast.
- There is no evidence of life anywhere else yet.
- Finding microbial life elsewhere is very hard. But finding intelligent life willing to communicate is easier.
- How common is intelligent life? Are we a necessary step in the evolution of life on Earth?
- "*Sharks are dumb and they have been around for hundreds of millions of years*."

Drake Equation

- Frank Drake (born 1930, Chicago) is one of the pioneers of SETI (*Search for Extra-Terrestrial Intelligence*).
- Presented his equation at the meeting of SETI enthusiasts at the Green Bank Radio Observatory in 1960.
- Number of civilizations in the Galaxy with which we can communicate:

$$N = SFR \times f_P \times n_{HZ} \times f_L \times f_I \times f_C \times t_C$$

Drake Factors

Factor	*Optimistic*	*Pessimistic*
SFR	5/yr	10/yr
f_P	0.5	1
n_{HZ}	1	1
f_L	1	1
f_I	0.01	1
f_C	0.01	$t_C/(10kyr+t_C)$
t_C	70yr	10,000yr
N	0.0175	50,000

Fermi Paradox

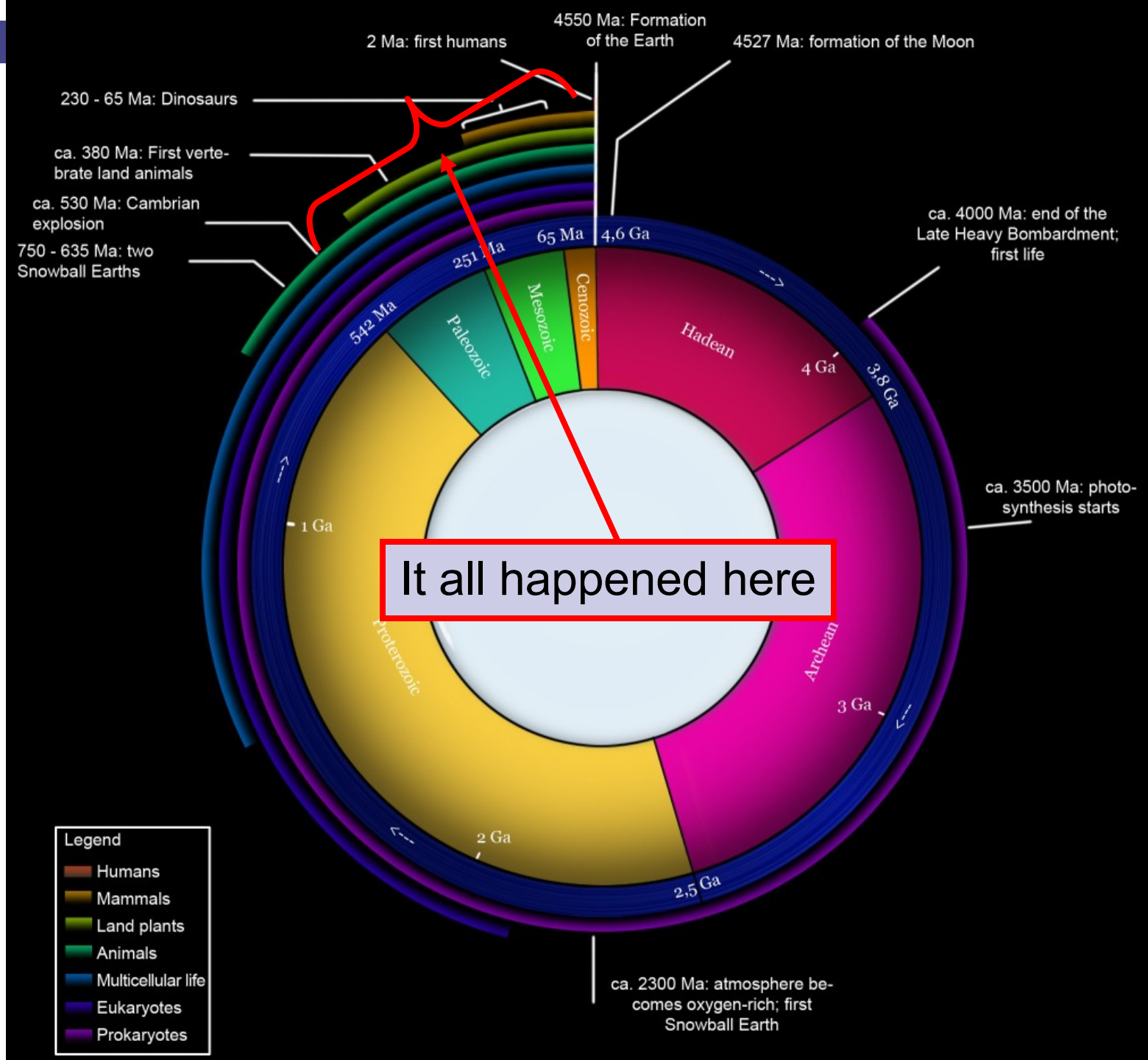
- "Where are they?" If the pessimistic values for Drake parameters are correct, there should be thousands of civilizations in the Galaxy. Never-the-less, we are not conquered yet.
- Formulated by Enrico Fermi in 1950.
- Alternatively, can be phrased as ***Great Silence*** – where are the signals from other civilizations?
- Possible solutions:
  - Optimistic values for Drake's parameters.
  - The Great Filter.

The Great Filter

- Steps to space - traveling civilization:
  - ☑ The right star system (including organics)
  - ☑ Reproductive something (e.g. DNA)
  - ☑ Simple (prokaryotic) single-cell life
  - ☑ Complex (archaeatic & eukaryotic) single-cell life
  - ☑ Sexual reproduction
  - ? ☐ Animals
  - ☐ Tool-using animals with big brains
  - ☐ Colonization explosion
- *"The easier it was for life to evolve to our stage, the bleaker our future chances probably are."*

Rare Earth Hypothesis

- Proposed by Peter Ward in 2000. Argues that multi-cellar life must be rare.
- Partially contradicts Copernican Principle (the Earth is a typical rocky planet in a typical (?) planetary system, located in an unexceptional region of a common barred-spiral galaxy).
- We still do not know how common/peculiar the Solar system is (Kepler mission should help).
- We still do not know what caused ***Cambrian Explosion***.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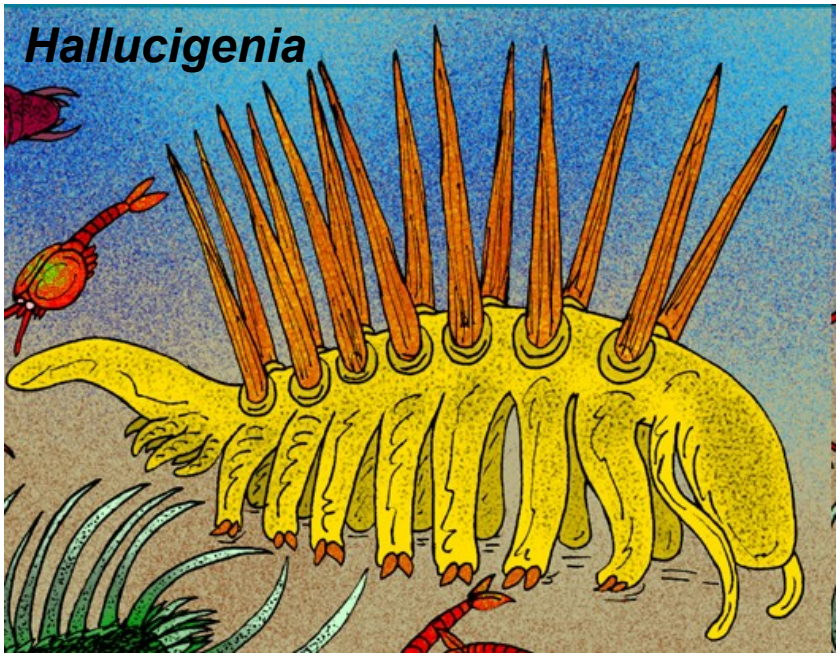
Cambrian Explosion

- Most of known types of animals appeared in 70-80 million years from ~580 to ~500 Myr ago.
- Many weird creatures existed then, but died out.



Interstellar Travel

- Ok, let's imagine we finally found someone. How do we go visit? (Or, we reached the stage of colonial expansion, if it happens.)
- Special Relativity (SR) limits the speed of any interstellar travel to below the speed of light (300,000 km/s = 7.2 uph).
- Interstellar distances are humongous:
  - Proxima Centari: 4.22 lyr.
  - Center of the Galaxy: 27,700 lyr.

Time Dilation

- In SR time is relative; on an accelerating - decelerating spaceship time flows slower.

$$\Delta t_{\mathrm{SHIP}} = \Delta t_{\mathrm{EARTH}} \sqrt{1 - v^2/c^2}$$

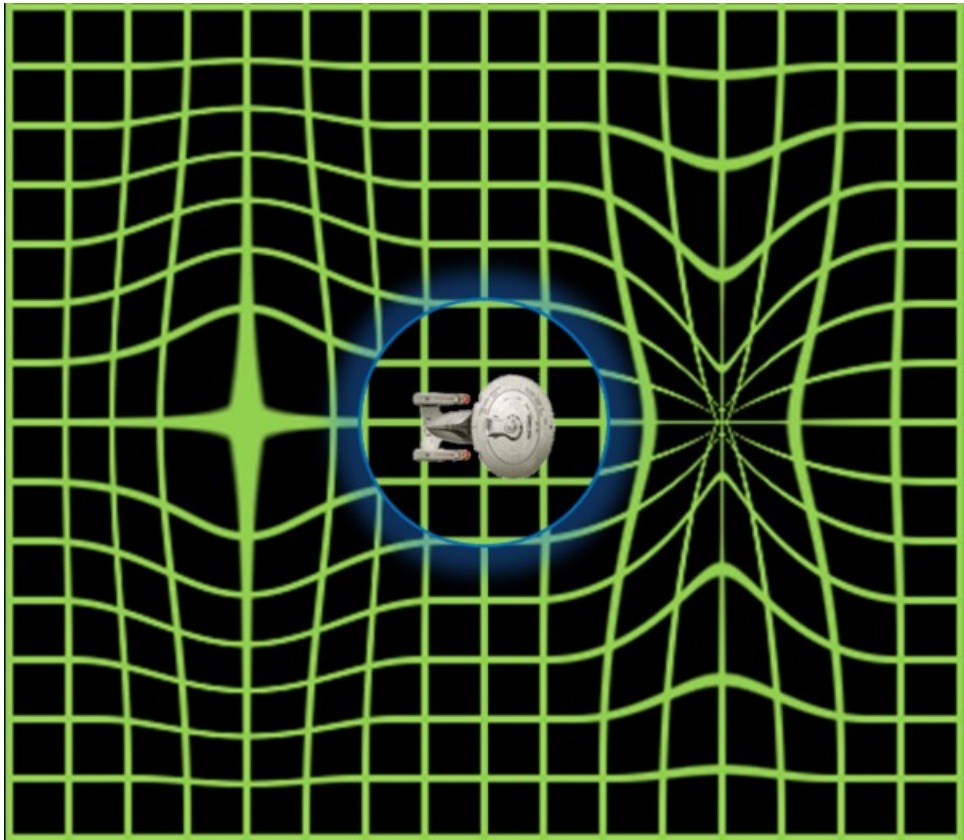
v/c	Slow-down factor
0.9	2.3
0.99	7.1
0.999	22.4
0.9999	70.7

Center of the Galaxy

- To reach the center of the Milky Way in 10 years, one has to travel on average at 0.999,999,935c.
- To send a 1,000 ton spaceship with such a speed requires all the energy the Sun emits in 1 second.
- Theoretically, this seems possible. But what's the point? – travelers will incur a 54,000 year time difference!

Alcubierre Warp Drive

- In 1994 Miguel Alcubierre discoverd a “warp drive” space-time.
- His space-time allows travel with arbitrary speed (relative to the rest of the Galaxy) with no time delay incurred.
- It remains unclear whether this is practical energetically.



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